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Kamiya

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(54) **EFFICIENT XML INTERCHANGE SCHEMA DOCUMENT ENCODING**

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CPC ***G06F 17/2205*** (2013.01); ***G06F 17/2247*** (2013.01); ***G06F 17/2258*** (2013.01)

(58) **Field of Classification Search**
CPC G06F 17/2247
See application file for complete search history.

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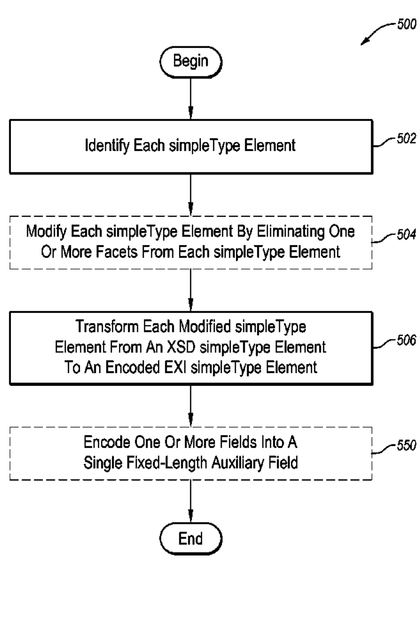
(57) **ABSTRACT**

A method of reducing the size of a simpleType element in an Efficient XML Interchange (EXI) schema document may include modifying each simpleType element in an XSD document by eliminating one or more facets from each simpleType element. The method may also include encoding the XSD document into an EXI schema document by transforming each modified simpleType element in the XSD document from an XSD simpleType element with start and end tags to an encoded EXI simpleType element expressed as a sequence of bits.

20 Claims, 13 Drawing Sheets



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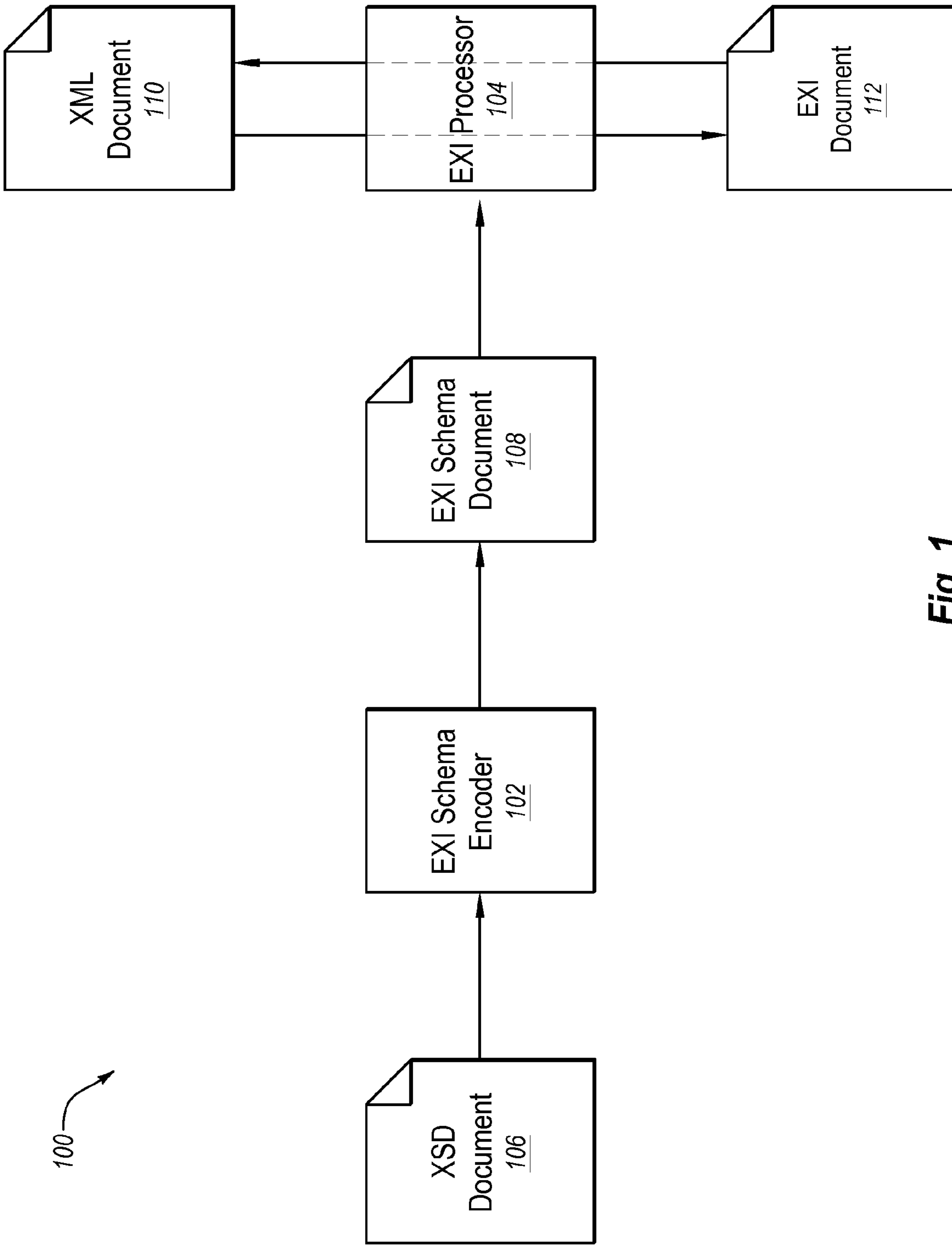


XML Document 110
EXI Processor 104
EXI Document 112
EXI Schema Document 108
EXI Schema Encoder 102
XSD Document 106
100

Fig. 1

200

```
public static final int NODE_TYPE = 0;
public static final int TYPE_NAME = 1;
public static final int TYPE_TARGET_NAMESPACE = 2;
public static final int TYPE_NUMBER = 3;
public static final int TYPE_GRAMMAR = 4;
public static final int SIMPLE_TYPE_AUX = 5;
public static final int SIMPLE_TYPE_FIELD_INT = 6;
public static final int SIMPLE_TYPE_NEXT_SIMPLE_TYPE = 7;
```

Fig. 2

300

```
static final int NODE_TYPE = 0;
static final int TYPE_NAME = 1;
static final int TYPE_TARGET_NAMESPACE = 2;
static final int TYPE_NUMBER = 3;
static final int TYPE_BASE_TYPE = 4;
static final int TYPE_BOOLEANS = 5;
static final int TYPE_ISURTYPE_MASK = 0x0001;
static final int TYPE_ISFIXTURE_MASK = 0x0002;
static final int SIMPLE_TYPE_VARIETY = 6; // atomic, list or union
static final int SIMPLE_TYPE_AUX_TYPE = 7;
static final int SIMPLE_TYPE_BOOLEANS = 8;
static final int SIMPLE_TYPE_ISBUILTIN_MASK = 0x0001;
static final int SIMPLE_TYPE_ISPRIMITIVE_MASK = 0x0002;
static final int SIMPLE_TYPE_ISNUMERIC_MASK = 0x0004;
static final int SIMPLE_TYPE_ISLIST_CONTENT_MASK = 0x0008;
static final int SIMPLE_TYPE_ISENUM_CONTENT_MASK = 0x0010;
static final int SIMPLE_TYPE_ISEMPTIABLE_MASK = 0x0020;
static final int SIMPLE_TYPE_FACET_LENGTH = 9; // int
static final int SIMPLE_TYPE_FACET_MINLENGTH = 10; // int
static final int SIMPLE_TYPE_FACET_MAXLENGTH = 11; // int
static final int SIMPLE_TYPE_FACET_WHITESPACE = 12; // int
static final int SIMPLE_TYPE_FACET_MAXINCLUSIVE = 13; // variant
static final int SIMPLE_TYPE_FACET_MAXEXCLUSIVE = 14; // variant
static final int SIMPLE_TYPE_FACET_MINEXCLUSIVE = 15; // variant
static final int SIMPLE_TYPE_FACET_MININCLUSIVE = 16; // variant
static final int SIMPLE_TYPE_FACET_TOTALDIGITS = 17; // int
static final int SIMPLE_TYPE_FACET_FRACTIONDIGITS = 18; // int
static final int SIMPLE_TYPE_N_FACET_PATTERNS = 19; // int
static final int SIMPLE_TYPE_N_FACET_ENUMERATIONS = 20; // int
static final int SIMPLE_TYPE_N_MEMBER_TYPES = 21;
static final int SIMPLE_TYPE_NEXT_SIMPLE_TYPE = 22;
```

Fig. 3
Prior Art

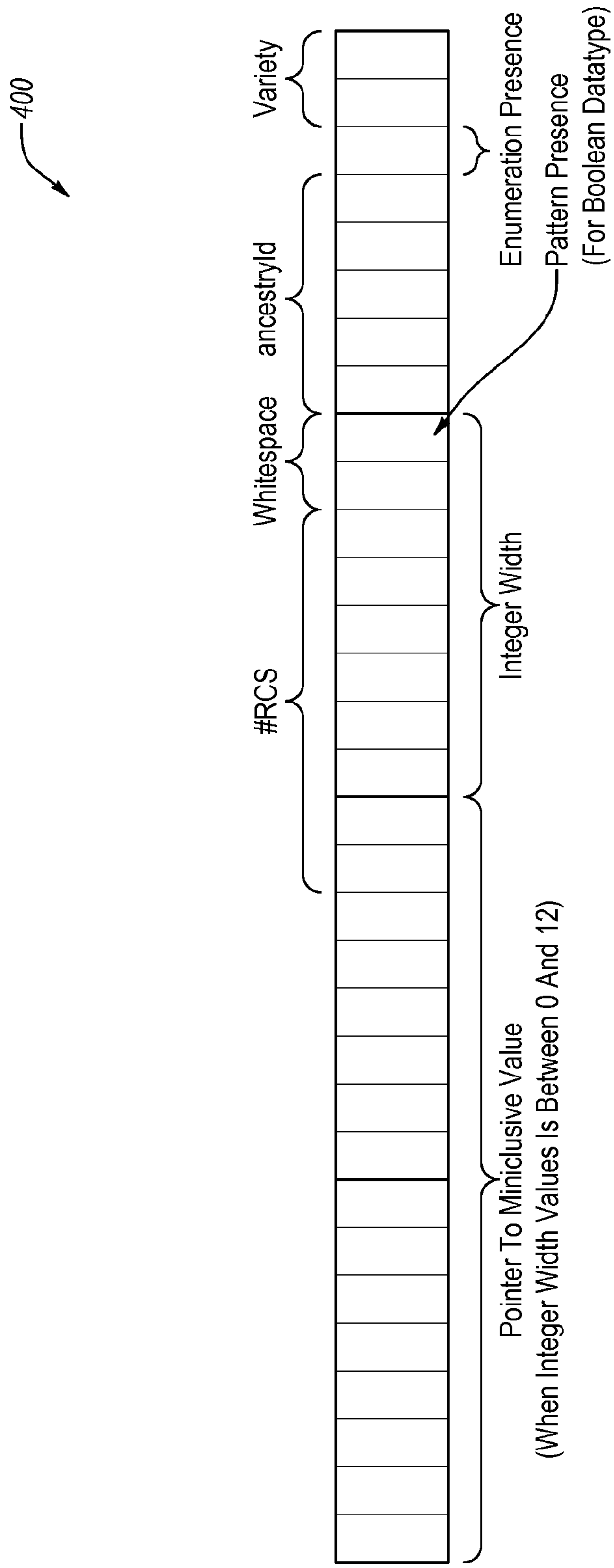

400
Variety
ancestryId
Whitespace
#RCS
Enumeration Presence
Pattern Presence
(For Boolean Datatype)
Integer Width
Pointer To Miniclusive Value
(When Integer Width Values Is Between 0 And 12)

Fig. 4

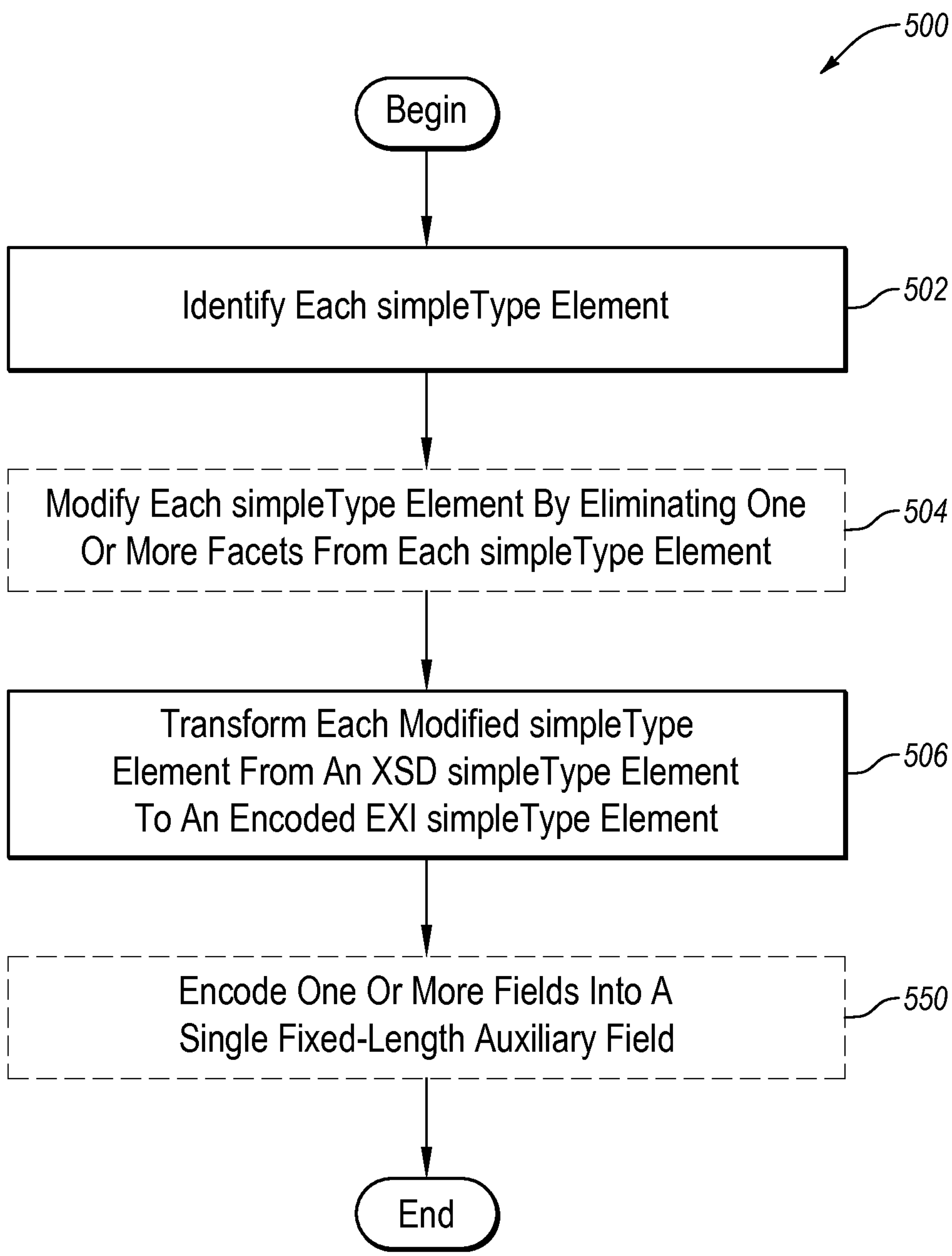
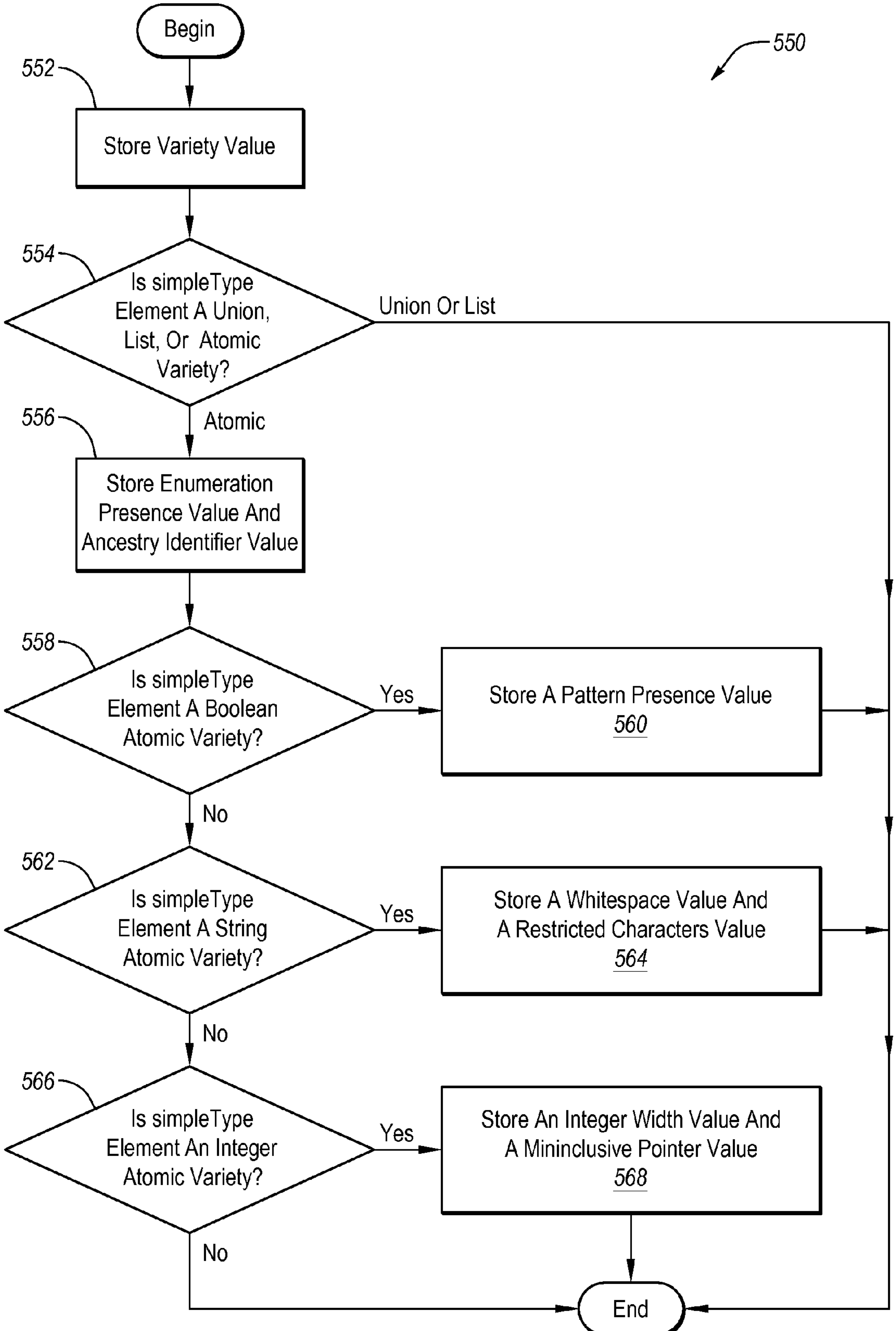

500
Begin
Identify Each simpleType Element
502
Modify Each simpleType Element By Eliminating One Or More Facets From Each simpleType Element
504
Transform Each Modified simpleType Element From An XSD simpleType Element To An Encoded EXI simpleType Element
506
Encode One Or More Fields Into A Single Fixed-Length Auxiliary Field
550
End

Fig. 5A



550
Begin
552
Store Variety Value
554
Is simpleType Element A Union, List, Or Atomic Variety?
Union Or List
Atomic
556
Store Enumeration Presence Value And Ancestry Identifier Value
558
Is simpleType Element A Boolean Atomic Variety?
Yes
Store A Pattern Presence Value
560
No
562
Is simpleType Element A String Atomic Variety?
Yes
Store A Whitespace Value And A Restricted Characters Value
564
No
566
Is simpleType Element An Integer Atomic Variety?
Yes
Store An Integer Width Value And A Mininclusive Pointer Value
568
No
End

Fig. 5B

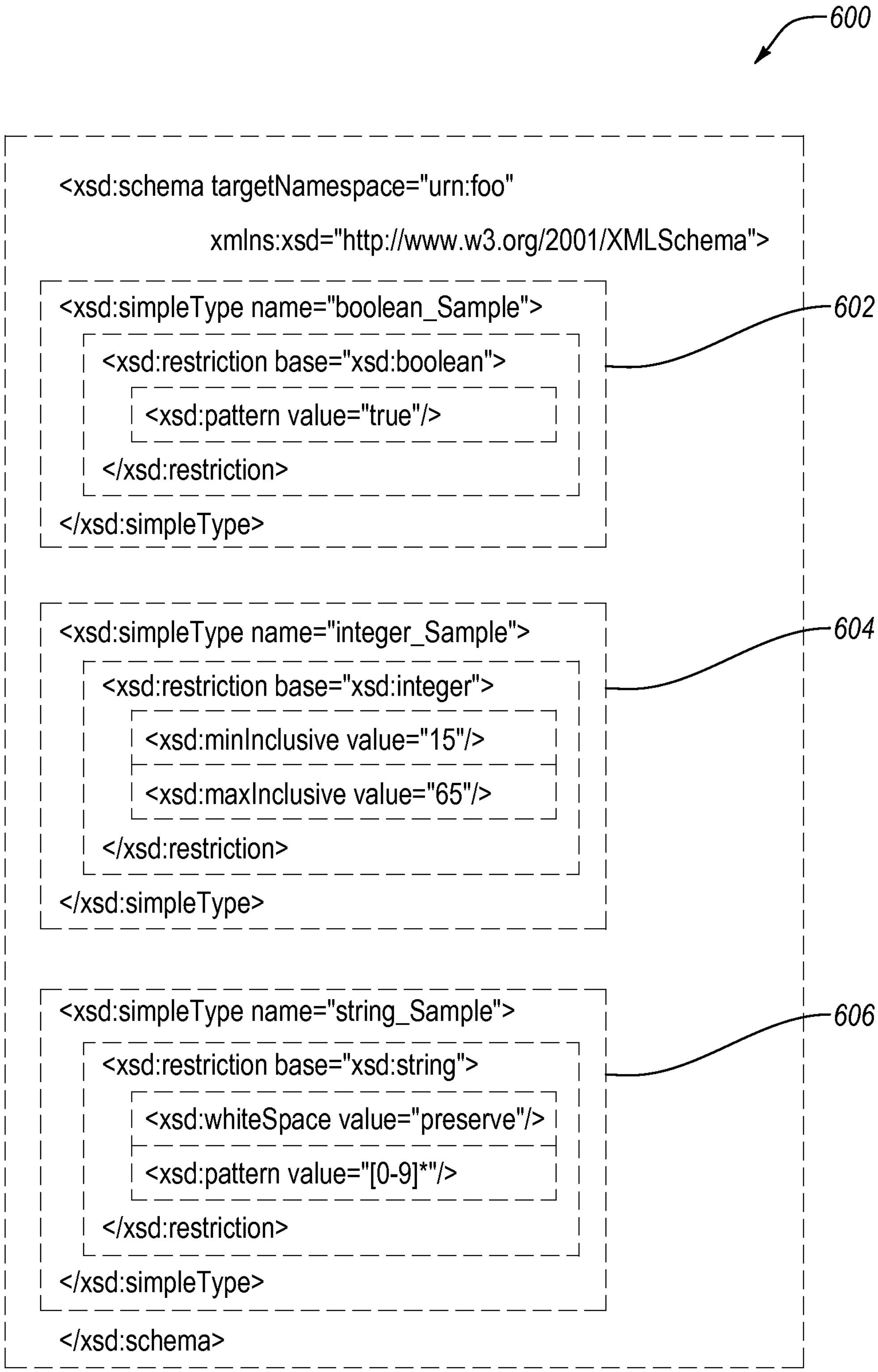

600
<xsd:schema targetNamespace="urn:foo"
xmlns:xsd="http://www.w3.org/2001/XMLSchema">
<xsd:simpleType name="boolean_Sample">
<xsd:restriction base="xsd:boolean">
<xsd:pattern value="true"/>
</xsd:restriction>
</xsd:simpleType>
602
<xsd:simpleType name="integer_Sample">
<xsd:restriction base="xsd:integer">
<xsd:minInclusive value="15"/>
<xsd:maxInclusive value="65"/>
</xsd:restriction>
</xsd:simpleType>
604
<xsd:simpleType name="string_Sample">
<xsd:restriction base="xsd:string">
<xsd:whiteSpace value="preserve"/>
<xsd:pattern value="[0-9]*"/>
</xsd:restriction>
</xsd:simpleType>
606
</xsd:schema>

Fig. 6

700

boolean_Sample							
	Field	**Byte 0**	**Byte 1**	**Byte 3**	**Byte 4**	**Decimal Value**	**Value**
int[addr]	Node Type	00000000	00000000	00000001	00000001	257	Simple Type
int[addr+1]	Name	00000000	00000000	00000000	00000001	1	boolean_Sample
int[addr+2]	URI	00000000	00000000	00000000	00000100	4	urn:foo
int[addr+3]	Type Serial Number	00000000	00000000	00000000	00110010	50	50
int[addr+4]	Grammar Address	00000000	00000000	00000011	11010000	976	976
int[addr+5]	Auxiliary Bits	00000000	00000000	00000001	00011001	281	Composite Value 281
int[addr+6]	Base Type	00000000	00000000	00000000	00010111	23	xsd:boolean
int[addr+7]	Next Simple Type Address	00000000	00000000	00000001	11000111	455	455

Fig. 7

800

integer_Sample							
	Field	**Byte 0**	**Byte 1**	**Byte 3**	**Byte 4**	**Decimal Value**	**Value**
int[addr]	Node Type	00000000	00000000	00000001	00000001	257	Simple Type
int[addr+1]	Name	00000000	00000000	00000000	00000100	4	integer_Sample
int[addr+2]	URI	00000000	00000000	00000000	00000100	4	urn:foo
int[addr+3]	Type Serial Number	00000000	00000000	00000000	00110000	48	48
int[addr+4]	Grammar Address	00000000	00000000	00000011	10101010	938	938
int[addr+5]	Auxiliary Bits	00000000	00001011	00000110	10101001	722601	Composite Value 722601
int[addr+6]	Base Type	00000000	00000000	00000000	10111001	185	xsd:integer
int[addr+7]	Next Simple Type Address	00000000	00000000	00000001	10110101	437	437

Fig. 8

900

string_Sample							
	Field	**Byte 0**	**Byte 1**	**Byte 3**	**Byte 4**	**Decimal Value**	**Value**
int[addr]	Node Type	00000000	00000000	00000001	00000001	257	Simple Type
int[addr+1]	Name	00000000	00000000	00000000	00000110	6	string_Sample
int[addr+2]	URI	00000000	00000000	00000000	00000100	4	urn:foo
int[addr+3]	Type Serial Number	00000000	00000000	00000000	00110100	52	52
int[addr+4]	Grammar Address	00000000	00000000	00000011	11110110	1014	1014
int[addr+5]	Auxiliary Bits	00000000	00000000	00101001	00010001	10513	Composite Value 10513
int[addr+6]	Base Type	00000000	00000000	00000000	00001110	14	xsd:string
int[addr+7]	Next Simple Type Address	11111111	11111111	11111111	11111111	-1	none

Fig. 9

1000

string_Sample							
	Field	**Byte 0**	**Byte 1**	**Byte 3**	**Byte 4**	**Decimal Value**	**Value**
int[addr]	Node Type	00000000	00000000	00000001	00000001	257	Simple Type
int[addr+1]	Name	00000000	00000000	00000000	00010000	16	string_Sample
int[addr+2]	URI	00000000	00000000	00000000	00000011	3	urn:foo
int[addr+3]	Type Serial Number	00000000	00000000	00000000	00110100	52	52
int[addr+4]	Base Type Address	00000000	00000000	00000000	10001011	139	xsd:string
int[addr+5]	Type Boolean Bits	00000000	00000000	00000000	00000000	0	Composite Value 0
int[addr+6]	Variety	00000000	00000000	00000000	00000010	2	atomic
int[addr+7]	Built-in Type Address	00000000	00000000	00000000	10001011	139	xsd:string

Continued On 10B

Fig. 10A
Prior Art

Continued On 10B

Continued On 10A

int[addr+8]	SimpleType Boolean Bits	00000000	00000000	00000000	00000000	0	Composite Value 0
int[addr+9]	Length Facet	11111111	11111111	11111111	11111111	-1	none
int[addr+10]	minLength Facet	11111111	11111111	11111111	11111111	-1	none
int[addr+11]	maxLength Facet	11111111	11111111	11111111	11111111	-1	none
int[addr+12]	whiteSpace Facet	00000000	00000000	00000000	00000000	0	preserve
int[addr+13]	maxInclusive Facet	11111111	11111111	11111111	11111111	-1	none
int[addr+14]	maxExclusive Facet	11111111	11111111	11111111	11111111	-1	none
int[addr+15]	minExclusive Facet	11111111	11111111	11111111	11111111	-1	none
int[addr+16]	minInclusive Facet	11111111	11111111	11111111	11111111	-1	none

Continued On 10C

Fig. 10B
Prior Art

Continued On 10B

int[addr+17]	totalDigits Facet	11111111	11111111	11111111	11111111	-1	none
int[addr+18]	fractionDigits Facet	11111111	11111111	11111111	11111111	-1	none
int[addr+19]	# of RCS	00000000	00000000	00000000	00001010	10	10 (i.e.-0-9)
int[addr+20]	# of Enumerations	00000000	00000000	00000000	00000000	0	0
int[addr+21]	# of Member Types	00000000	00000000	00000000	00000000	0	0
int[addr+22]	Next Simple Type Address	11111111	11111111	11111111	11111111	-1	none

Fig. 10C
Prior Art

EFFICIENT XML INTERCHANGE SCHEMA DOCUMENT ENCODING

FIELD

The embodiments discussed herein are related to Efficient XML Interchange (EXI) schema documents.

BACKGROUND

Extensible Markup Language (XML) is a markup language that defines a set of rules for encoding documents in a plain-text format that is both human-readable and machine-readable. One version of XML is defined in the XML 1.0 Specification produced by the World Wide Web Consortium (W3C) and dated Nov. 26, 2008, which is incorporated herein by reference in its entirety. The XML 1.0 Specification defines an XML document as a text that is well-formed and valid.

An XML schema is a description of a type of XML document, typically expressed in terms of constraints on the structure and content of documents of that type, above and beyond the basic syntactical constraints imposed by the XML 1.0 Specification itself. These constraints are generally expressed using some combination of grammatical rules governing the order of elements, boolean predicates associated with the content, data types governing the content of elements and attributes, and more specialized rules such as uniqueness and referential integrity constraints. One example schema language in widespread use is the XML Schema Definition (XSD) language as defined in the XSD 1.1 Specification produced by the W3C and dated Apr. 5, 2012, which is incorporated herein by reference in its entirety.

The process of checking to see if an XML document conforms to an XSD document is called validation, which is separate from XML's core concept of syntactic well-formedness. All XML documents are defined as being well-formed, but an XML document is on check for validity where the XML processor is "validating," in which case the document is checked for conformance with its associated XSD document. An XML document is only considered valid if it satisfies the requirements of the XSD document with which it has been associated.

Although the plain-text human-readable aspect of XML and XSD documents may be beneficial in many situations, this human-readable aspect may also lead to XML and XSD documents that are large in size and therefore incompatible with devices with limited memory or storage capacity. Efforts to reduce the size of XML and XSD documents have therefore often eliminated this plain-text human-readable aspect in favor of more compact binary representations.

EXI is a Binary XML format. EXI is one of the most prominent binary XML efforts to encode XML documents in a binary data format rather than plain text. In general, using a binary XML format reduces the size and verbosity of XML documents, and may reduce the cost in terms of time and effort involved in parsing XML documents. EXI is formally defined in the EXI Format 1.0 Specification produced by the W3C and dated Mar. 10, 2011, which is incorporated herein by reference in its entirety. An XML document may be encoded in an EXI format as a separate EXI document. An XSD document may also be encoded as a separate EXI schema document.

When an XSD document is encoded as an EXI schema document, the EXI schema document generally includes various encoded data fields that are employed in validation tasks. Unfortunately, however, the inclusion of these various

encoded data fields may cause the size of the EXI schema document to remain relatively large in size. This relatively large size may be problematic where the EXI schema document is transferred to an EXI processor that is employed in a device with limited memory or storage capacity.

The subject matter claimed herein is not limited to embodiments that solve any disadvantages or that operate only in environments such as those described above. Rather, this background is only provided to illustrate one example technology area where some embodiments described herein may be practiced.

SUMMARY

According to an aspect of an embodiment, a method of reducing the size of a simpleType element in an EXI schema document may include modifying each simpleType element in an XSD document by eliminating one or more facets from each simpleType element. The method may also include encoding the XSD document into an EXI schema document by transforming each modified simpleType element in the XSD document from an XSD simpleType element with start and end tags to an encoded EXI simpleType element expressed as a sequence of bits.

The object and advantages of the embodiments will be realized and achieved at least by the elements, features, and combinations particularly pointed out in the claims.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are not restrictive of the invention, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

Example embodiments will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

FIG. **1** is a block diagram of an example EXI processing system;

FIG. **2** illustrates an example EXI schema simpleType datatype according to at least some embodiments described herein;

FIG. **3** illustrates a prior art EXI schema simpleType datatype;

FIG. **4** illustrates an example layout of an auxiliary field in the example EXI schema datatype of FIG. **2**;

FIG. **5**A is a flow chart of an example method of reducing the size of a simpleType element in an EXI schema document;

FIG. **5**B is an expanded flow chart of an example method of one block of the example method of FIG. **5**A;

FIG. **6** illustrates an example XSD document;

FIG. **7** illustrates an example atomic boolean simpleType element of the XSD document of FIG. **6** that has been encoded according to the example EXI schema datatype of FIG. **2**;

FIG. **8** illustrates an example atomic integer simpleType element of the XSD document of FIG. **6** that has been encoded according to the example EXI schema datatype of FIG. **2**;

FIG. **9** illustrates an example atomic string simpleType element of the XSD document of FIG. **6** that has been encoded according to the example EXI schema datatype of FIG. **2**; and

FIGS. **10**A-**10**C illustrate an example string element of the XSD document of FIG. **6** that has been encoded according to the prior art EXI schema datatype of FIG. **3**.

DESCRIPTION OF EMBODIMENTS

Some embodiments described herein may include methods of reducing the size of a simpleType element in an EXI schema document. For example, some embodiments described herein may include a method of reducing the size of a simpleType element in an EXI schema document where the EXI schema document is targeted for non-validation tasks. Because validation tasks employ validation-specific data fields of a simpleType element, where an EXI schema document is targeted for a non-validation task, the size of the simpleType element in the EXI schema document may be reduced by eliminating these validation-specific data fields.

As used herein, the term "document" refers to any electronic document, stream, or file. Therefore, as used herein, the phrase "EXI schema document" is synonymous with "EXI schema stream" or "EXI schema file."

Embodiments of the present invention will be explained with reference to the accompanying drawings.

FIG. **1** is a block diagram of an example EXI processing system **100**, arranged in accordance with at least some embodiments described herein. The EXI processing system **100** may include an EXI schema encoder **102** and an EXI processor **104**. An example EXI schema encoder and an example EXI processor are included in the OpenEXI project hosted at SourceForge.net. The source code and documentation of the OpenEXI project as of the filing date of the present application are incorporated herein by reference in their entirety. The EXI schema encoder **102** is configured to receive as input an XSD document **106** and encode the XSD document **106** into an EXI schema document **108**. For example, the EXISchemaFactory of the OpenEXI project may be employed as the EXI schema encoder **102**. The EXI schema document **108** may then be received as input to the EXI processor **104** and used when converting between an associated XML document **110** and its corresponding EXI document **112**. The EXI processor **104** may be employed in a device with limited memory or storage capacity.

FIG. **2** illustrates an example EXI schema simpleType datatype **200** according to at least some embodiments described herein. The example EXI schema datatype **200** may be employed by the EXI schema encoder **102** of FIG. **1** when encoding the XSD document **106** into the EXI schema document **108**. In the illustrated embodiment, the EXI schema datatype **200** includes eight (8) fields that each occupies four (4) bytes in memory. Therefore, the EXI schema datatype **200** occupies thirty-two (32) bytes in memory (i.e. 8 fields×4 bytes=32 bytes) according to some embodiments. It is understood that the specific number of fields in the example EXI schema datatype **200** may differ in other embodiments from the number shown in FIG. **2**. It is further understood that the number of bytes that each field occupies in memory in the example EXI schema datatype **200** may differ in other embodiments from the number shown in FIG. **2**.

FIG. **3** illustrates a prior art EXI schema simpleType datatype **300**. The prior art EXI schema simpleType datatype **300** includes twenty-three (23) fields that each occupies four (4) bytes in memory. Therefore, the prior art EXI schema simpleType datatype **300** occupies ninety-two (92) bytes in memory (i.e. 23 fields×4 bytes=92 bytes). Thus, the example EXI schema simpleType datatype **200** occupies 65% less memory space than the prior art EXI schema simpleType datatype **300** (i.e. 100%−32 bytes/92 bytes=65%). This reduction in the amount of memory occupied by the example EXI schema simpleType datatype **200** reduces the size of a simpleType element in an encoded EXI schema. This reduction in the amount of memory may generally be accomplished by eliminating various validation-specific facets from each simpleType element. The term "facet" as used herein refers to a facet as defined in the EXI Format 1.0 Specification.

For example, a comparison of the example EXI schema simpleType datatype **200** and the prior art EXI schema simpleType datatype **300** reveals that various facets may be eliminated from each simpleType element in an XSD document. Then, when the XSD document is encoded into an EXI schema document, the prior elimination of these facets may result in a reduction in the size of each simpleType element in the encoded EXI schema document. The encoded EXI schema document may then be utilized in any task other than XML validation. Examples of non-validation tasks include, but are not limited to, encoding an XML document into an EXI document, decoding an XML document from an EXI document, encoding an XML document into a Comma-Separated Values (CSV) document, a flat file document, or a JavaScript Object Notation (JSON) document; and decoding an XML document from a CSV document, a flat file document, or a JSON document.

As suggested by a comparison of the example EXI schema simpleType datatype **200** and the prior art EXI schema simpleType datatype **300**, the eliminated facets may include length, minLength, maxLength, pattern, maxInclusive, maxExclusive, minExclusive, totalDigits, and fractionDigits for all varieties of simpleType elements. In addition, the eliminated facets may further include minInclusive for each simpleType element other than integer atomic variety simpleType elements that are a bounded integer. Moreover, the eliminated facets may further include whitespace for each simpleType element other than string atomic variety simpleType elements.

Instead of outright elimination of a particular facet, the facet may instead be reduced in size and combined with other facets in a composite auxiliary field, thereby maintaining at least a portion of the facet value while still furthering the goal of an overall reduction in the size of the corresponding simpleType element. FIG. **4** illustrates an example layout **400** of the SIMPLE_TYPE_AUX field in the example EXI schema simpleType datatype **200** of FIG. **2**. The example layout **400** includes thirty-two (32) bits that, depending on the variety of the simpleType element, are used as various data fields to encode corresponding data values. For example, the data fields of the example layout **400** may be used to encode at least a portion of various facet values, thereby reducing the amount of memory used by not storing the entire facet value.

For example, the example layout **400** includes a 2-bit variety field for all simpleType element varieties, including list, union, and atomic varieties. Where the simpleType element is any atomic variety, the example layout **400** further includes a 1-bit enumeration presence field and a 5-bit ancestry identifier field. Where the simpleType element is a boolean atomic variety, the example layout **400** further includes a 1-bit pattern presence field. Where the simpleType element is a string atomic variety, the example layout **400** further includes a 2-bit whitespace field and an 8-bit restricted characters field. Where the simpleType element is an integer atomic variety, the example layout **400** further includes an 8-bit integer width field and a 16-bit minInclusive pointer field. It is understood that the specific number of bits in each field in the example layout **400** in other embodiments may differ from the number shown in FIG. **4**.

FIG. **5**A is a flow chart of an example method **500** of reducing the size of a simpleType element in an EXI schema document, arranged in accordance with at least some embodiments described herein. The method **500** may be implemented, in some embodiments, by an EXI processing system, such as the example EXI processing system **100** of FIG. **1**. For example, the EXI schema encoder **102** of the EXI processing system **100** of FIG. **1** may be configured to execute computer instructions to perform operations of reducing the size of a simpleType element from the XSD document **106** during the encoding of the simpleType element into the EXI schema document **108**, as represented by one or more of blocks **502**, **504**, **506** and/or **550** of the method **500**. Although illustrated as discrete blocks, various blocks may be divided into additional blocks, combined into fewer blocks, or eliminated, depending on the desired implementation. The method **500** will now be discussed with reference to both FIG. **5**A and FIG. **1**.

The method **500** may begin at block **502**, in which each simpleType element in an XSD document is identified. For example, the EXI schema encoder **102** may parse through the XSD document **106** to identify each simpleType element in the XSD document **106**.

In optional block **504**, each simpleType element of the XSD document is modified by eliminating one or more facets from each simpleType element in the XSD document. For example, the EXI schema encoder **102** may eliminate one or more facets from each simpleType element in the XSD document **106**. As noted above, in at least some example embodiments, these eliminated facets may include validation-specific facets from each simpleType element, such as those listed above.

In block **506**, each modified simpleType element in the XSD document is transformed from an XSD simpleType element to an encoded EXI simpleType element. For example, the EXI schema encoder **102** may transform each modified simpleType element with start and end tags in the XSD document **106** to an encoded EXI simpleType element expressed as a sequence of bits in the encoded EXI schema document **108**.

In optional block **550**, one or more fields of each simpleType element in the XSD document are encoded into a single fixed-length auxiliary field in the encoded EXI simpleType element. For example, the EXI schema encoder **102** may encode one or more fields of each simpleType element in the XSD document **106** into a single fixed-length auxiliary field in the corresponding encoded EXI simpleType element in the encoded EXI schema document **108**. The fixed-length auxiliary field may be the SIMPLE_TYPE_AUX field with the example layout **400** of FIG. **4**.

FIG. **5**B is an expanded flow chart of an example method of the block **550** (hereinafter the "method **550**") of the example method **500** of FIG. **5**A. The method **550** will now be discussed with reference to FIG. **5**B, FIG. **1**, and FIG. **4**.

The method **550** may begin at block **552**, in which the variety value of the simpleType element is stored. For example, the EXI schema encoder **102** may store the variety value of a simpleType element of the XSD document **106** in the 2-bit variety field of the example layout **400** in the EXI schema document **108**.

In decision block **554**, it is determined whether the simpleType element is a union, list, or atomic variety. If the simpleType element is a union or list variety ("Union or List" at decision block **504**), then the method **550** is complete. If the simpleType element is an atomic variety ("Atomic" at decision block **504**), then the method **550** proceeds to block **556**. For example, the EXI schema encoder **102** may examine the variety of the simpleType element of the XSD document **106** to determine whether the simpleType element is a union, list, or atomic variety.

In block **556**, an enumeration presence value and an ancestry identifier value of the simpleType element are stored. For example, the EXI schema encoder **102** may store the enumeration presence value of the simpleType element in the 1-bit enumeration presence field and the ancestry identifier value simpleType element in the 5-bit ancestry identifier field of the example layout **400** in the EXI schema document **108**.

In decision block **558**, it is determined whether the simpleType element is a boolean atomic variety. For example, the EXI schema encoder **102** may examine the variety of the simpleType element of the XSD document **106** to determine whether the simpleType element is a boolean atomic variety. If so ("Yes" at decision block **558**), then the method **550** proceeds to block **560** where a pattern presence value is stored. For example, the EXI schema encoder **102** may store the pattern presence value of the simpleType element in the 1-bit pattern presence field of the example layout **400** in the EXI schema document **108**. If not ("No" at decision block **558**), then the method **550** proceeds to decision block **562**.

In decision block **562**, it is determined whether the simpleType element is a string atomic variety. For example, the EXI schema encoder **102** may examine the variety of the simpleType element of the XSD document **106** to determine whether the simpleType element is a string atomic variety. If so ("Yes" at decision block **562**), then the method **550** proceeds to block **564** where a whitespace value and a restricted characters value are stored. For example, the EXI schema encoder **102** may store the whitespace value of the simpleType element in the 2-bit whitespace field and the restricted characters value of the simpleType element in the 8-bit restricted characters field of the example layout **400** in the EXI schema document **108**. If not ("No" at decision block **562**), then the method **550** proceeds to decision block **566**.

In decision block **566**, it is determined whether the simpleType element is an integer atomic variety. For example, the EXI schema encoder **102** may examine the variety of the simpleType element of the XSD document **106** to determine whether the simpleType element is an integer atomic variety. If so ("Yes" at decision block **566**), then the method **550** proceeds to block **568** where an integer width value and a mininclusive pointer value are stored. For example, the EXI schema encoder **102** may store the integer width value of the simpleType element in the 8-bit integer width field and the mininclusive pointer value of the simpleType element in the 16-bit restricted characters field of the example layout **400** in the EXI schema document **108**. 4. If not ("No" at decision block **566**), then the method **550** is complete.

FIG. **6** illustrates an example XML Schema Definition (XSD) document **600**. The example XSD document **600** defines an atomic boolean simpleType element **602**, an atomic integer simpleType element **604**, and an atomic string simpleType element **606**. Each of the simpleType elements **602**, **604**, and **606** is an XML element including start and end "xsd:simpleType" tags. The XSD document **600** is a plain-text human-readable document of ASCII text, where each ASCII character occupies one (1) byte in memory. Therefore, prior to be being encoded into an EXI schema document, such as the EXI schema document **108** of FIG. **1**, the XSD document **600** occupies more than six-hundred-fifty (650) bytes in memory, with each of the individual simpleType elements **602**, **604**, and **606** occupying more than one-hundred-sixty (160) bytes in memory.

FIG. **7** illustrates the example atomic boolean simpleType element **602** of the XSD document **600** of FIG. **6** as an encoded simpleType element **700** according to the example EXI schema datatype **200** of FIG. **2**. FIG. **8** illustrates the example atomic integer simpleType element **604** of the XSD document **600** of FIG. **6** as an encoded simpleType element **800** according to the example EXI schema datatype **200** of

FIG. 2. FIG. 9 illustrates the example atomic string simpleType element 606 of the XSD document 600 of FIG. 6 as an encoded simpleType element 900 according to the example EXI schema datatype 200 of FIG. 2.

As illustrated in FIGS. 7, 8, and 9, each of the encoded simpleType elements 700, 800, and 900 occupy only thirty-two (32) bytes once encoded into an EXI schema document, such as the EXI schema document 108 of FIG. 1. Therefore, compared to the unencoded simpleType elements 602, 604, and 606 of the XSD document 600 of FIG. 6, which, as noted above, each occupies more than one-hundred-sixty (160) bytes in memory, each of the encoded simpleType elements 700, 800, and 900 occupies at least 80% less space in memory (i.e. 100%−32 bytes/160 bytes=80%).

FIGS. 10A-10C illustrate the example atomic string simpleType element 606 of the XSD document of FIG. 6 as an encoded simpleType element 1000 according to the prior art EXI schema datatype of FIG. 3. As illustrated in FIGS. 10A-10C, the encoded simpleType element 1000 occupies eighty-eight (88) bytes once encoded into an EXI schema document. Therefore, compared to the encoded simpleType element 900 of FIG. 9 which was encoded according to an example embodiment, the prior art encoded simpleType element 1000 of FIGS. 10A-10C occupies 2.75 times more space in memory.

Therefore, the embodiments disclosed herein include methods of reducing the size of a simpleType element in an EXI schema document where the EXI schema document is targeted for non-validation tasks. Because validation tasks employ validation-specific data fields of a simpleType element, where an EXI schema document is targeted for a non-validation task, the size of the simpleType element in the EXI schema document may be reduced by eliminating these validation-specific data fields. Thus, the embodiment disclosed herein allow for more efficient exchange of schema information which may be especially beneficial in devices with limited memory or storage capacity.

The embodiments described herein may include the use of a special purpose or general-purpose computer including various computer hardware or software modules, as discussed in greater detail below.

Embodiments described herein may be implemented using computer-readable media for carrying or having computer-executable instructions or data structures stored thereon. Such computer-readable media may be any available media that may be accessed by a general purpose or special purpose computer. By way of example, and not limitation, such computer-readable media may include non-transitory computer-readable storage media including RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other storage medium which may be used to carry or store desired program code in the form of computer-executable instructions or data structures and which may be accessed by a general purpose or special purpose computer. Combinations of the above may also be included within the scope of computer-readable media.

Computer-executable instructions comprise, for example, instructions and data which cause a general purpose computer, special purpose computer, or special purpose processing device to perform a certain function or group of functions. Although the subject matter has been described in language specific to structural features and/or methodological acts, it is to be understood that the subject matter defined in the appended claims is not necessarily limited to the specific features or acts described above. Rather, the specific features and acts described above are disclosed as example forms of implementing the claims.

As used herein, the term "module" or "component" may refer to software objects or routines that execute on the computing system. The different components, modules, engines, and services described herein may be implemented as objects or processes that execute on the computing system (e.g., as separate threads). While the system and methods described herein are preferably implemented in software, implementations in hardware or a combination of software and hardware are also possible and contemplated. In this description, a "computing entity" may be any computing system as previously defined herein, or any module or combination of modulates running on a computing system.

All examples and conditional language recited herein are intended for pedagogical objects to aid the reader in understanding the invention and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Although embodiments of the present inventions have been described in detail, it should be understood that the various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. A method of reducing the size of a simpleType element in an Efficient XML Interchange (EXI) schema document, the method comprising:
   - modifying each simpleType element in an XML Schema Definition (XSD) document by eliminating one or more validation-specific facets from each simpleType element; and
   - encoding the XSD document into an EXI schema document by transforming each modified simpleType element in the XSD document from an XSD simpleType element with start and end tags to an encoded EXI simpleType element expressed as a sequence of bits,
   - wherein each of the one or more validation-specific facets includes a facet employed to validate whether a document conforms to the XSD.

2. The method according to claim 1, further comprising utilizing the encoded EXI schema document in a task other than XML validation.

3. The method according to claim 1, further comprising utilizing the encoded EXI schema document in a task of encoding an XML document into an EXI document.

4. The method according to claim 1, further comprising utilizing the encoded EXI schema document in a task of decoding an XML document from an EXI document.

5. The method according to claim 1, further comprising utilizing the encoded EXI schema document in a task of encoding an XML document into a Comma-Separated Values (CSV) document, a flat file document, or a JavaScript Object Notation (JSON document).

6. The method according to claim 1, further comprising utilizing the encoded EXI schema document in a task of decoding an XML document from a Comma-Separated Values (CSV) document, a flat file document, or a JavaScript Object Notation (JSON) document.

7. The method according to claim 1, wherein:
   - the eliminated one or more validation-specific facets include length, minLength, maxLength, pattern, maxInclusive, maxExclusive, minExclusive, totalDigits, and fractionDigits for all varieties of simpleType elements;
   - the eliminated one or more validation-specific facets further include minInclusive for each simpleType element

other than integer atomic variety simpleType elements that are a bounded integer; and

the eliminated one or more validation-specific facets further include whitespace for each simpleType element other than string atomic variety simpleType elements.

8. A non-transitory computer-readable medium storing a program that causes a processor to execute the method according to claim **1**.

9. A method of reducing the size of a simpleType element in an Efficient XML Interchange (EXI) schema document, the method comprising:

identifying each simpleType element in an XML Schema Definition (XSD) document;

encoding the XSD document into an EXI schema document by transforming each identified simpleType element in the XSD document from an XSD simpleType element with start and end tags to an encoded EXI simpleType element expressed as a sequence of bits, the encoding including, for each identified simpleType element, encoding the following fields into a single fixed-length auxiliary field:

a variety field for a union or list variety simpleType element;

a variety field, an enumeration presence field, an ancestry identifier field, and a pattern presence field for a boolean atomic variety simpleType element;

a variety field, an enumeration presence field, an ancestry identifier field, a whitespace field, and a restricted characters field for a string atomic variety simpleType element;

a variety field, an enumeration presence field, an ancestry identifier field, an integer width field, and a minInclusive pointer field for an integer atomic variety simpleType element; or

a variety field, an enumeration presence field, and an ancestry identifier field for any other atomic variety simpleType element.

10. The method according to claim **9**, wherein the length of the single fixed-length auxiliary field is 4 bytes.

11. The method according to claim **10**, wherein:

each variety field and each whitespace field has a length of 2 bits;

each enumeration presence field and each pattern presence field has a length of 1 bit;

each ancestry identifier field has a length of 5 bits;

each restricted characters field has a length of 8 bits;

each integer width field has a length of 8 bits; and

each minInclusive pointer field has a length of 16 bits.

12. The method according to claim **9**, further comprising utilizing the encoded EXI schema document in a task other than XML validation.

13. The method according to claim **12**, further comprising utilizing the encoded EXI schema document in a task of encoding an XML document into an EXI document, a Comma-Separated Values (CSV) document, a flat file document, or a JavaScript Object Notation (JSON) document.

14. The method according to claim **12**, further comprising utilizing the encoded EXI schema document in a task of decoding an XML document from an EXI document, a Comma-Separated Values (CSV) document, a flat file document, or a JavaScript Object Notation (JSON) document.

15. The method according to claim **12**, further comprising eliminating one or more facets from each identified simpleType element in the XSD document prior to encoding the XSD document into an EXI schema document.

16. The method according to claim **14**, wherein:

the eliminated one or more facets include length, minLength, maxLength, pattern, maxInclusive, maxExclusive, minExclusive, totalDigits, and fractionDigits for all varieties of simpleType elements;

the eliminated one or more facets further include minInclusive for each simpleType element other than integer atomic variety simpleType elements that are a bounded integer; and

the eliminated one or more facets further include whitespace for each simpleType element other than string atomic variety simpleType elements.

17. A non-transitory computer-readable medium storing a program that causes a processor to execute the method according to claim **9**.

18. A system including:

a non-transitory computer-readable medium storing a program; and

an Efficient XML Interchange (EXI) schema encoder including a processor configured to execute the program, the program configured to cause the processor to execute a method of reducing the size of a simpleType element in an Efficient XML Interchange (EXI) schema document, the method comprising:

modifying each simpleType element in an XML Schema Definition (XSD) document by eliminating one or more facets from each simpleType element;

encoding the XSD document into an EXI schema document by transforming each modified simpleType element in the XSD document from an XSD simpleType element with start and end tags to an encoded EXI simpleType element expressed as a sequence of bits, the encoding including, for each modified simpleType element, encoding the following fields into a single fixed-length auxiliary field:

a variety field for a union or list variety simpleType element;

a variety field, an enumeration presence field, an ancestry identifier field, and a pattern presence field for a boolean atomic variety simpleType element;

a variety field, an enumeration presence field, an ancestry identifier field, a whitespace field, and a restricted characters field for a string atomic variety simpleType element;

a variety field, an enumeration presence field, an ancestry identifier field, an integer width field, and a minInclusive pointer field for an integer atomic variety simpleType element; or

a variety field, an enumeration presence field, and an ancestry identifier field for any other atomic variety simpleType element.

19. The system according to claim **18**, wherein:

the eliminated one or more facets include length, minLength, maxLength, pattern, maxInclusive, maxExclusive, minExclusive, totalDigits, and fractionDigits for all varieties of simpleType elements;

the eliminated one or more facets further include minInclusive for each simpleType element other than integer atomic variety simpleType elements that are a bounded integer; and

the eliminated one or more facets further include whitespace for each simpleType element other than string atomic variety simpleType elements.

20. The system according to claim **18**, wherein the auxiliary field has a length of 4 bytes and includes:

a 2-bit variety field for a union or list variety simpleType element;

a 2-bit variety field, a 1-bit enumeration presence field, a 5-bit ancestry identifier field, and a 1-bit pattern presence field for a boolean atomic variety simpleType element;

a 2-bit variety field, a 1-bit enumeration presence field, a 5-bit ancestry identifier field, a 2-bit whitespace field, and an 8-bit restricted characters field for a string atomic variety simpleType element;

a 2-bit variety field, a 1-bit enumeration presence field, a 5-bit ancestry identifier field, a 8-bit integer width field, and a 16-bit minInclusive pointer field for an integer atomic variety simpleType element; or

a 2-bit variety field, a 1-bit enumeration presence field, and a 5-bit ancestry identifier field for any other atomic variety simpleType element.

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